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ABSTRACT: Poison baits are extensively used for commensal rodent control; considerable folk lore exists regarding the use of additives to induce rodents to come to and eat poison baits. This paper describes a rational evaluation of attractants and the influence of different odours in inducing Rattus norvegicus to feed at given locations. The influence of certain repellents was also examined. Tests consisted of attempts to induce rats to feed at non-preferred sites or to repel them from preferred sites. Place preference was the dominant factor in feeding by rats, and odours failed to influence feeding activity significantly.

INTRODUCTION

Control of commensal rodents has been accomplished by a wide variety of methods: the use of traps, poison gas, tracking dusts, dogs, cats and ferrets, proofing and poisoned food. Of these, poisoned food either in the solid or liquid phase, is the principle means for killing rats and mice. The value of an odorous compound strongly attractant to rats from a distance of ten feet or more, would be difficult to over-estimate. Such a compound would enable the rapid clearance of an infested premises by a few, highly toxic baits situated in completely protected positions.

The discovery of warfarin resistance in 1959 in common rats in Scotland (Boyle 1960) and of further outbreaks on the Welsh Borders has stimulated considerable research into alternative rodenticides to warfarin.

Materials have been studied principally from two points of view (1) palatability and (2) toxicity. Initially, laboratory rats are used to determine palatability, but it is recognised that the results can only serve as a guide, since the taste preferences of wild rats may differ substantially from those of laboratory animals.

The differences are not only physiological but behavioral. Probably the most important factor is the existence of 'neophobia' or new object reaction, comprehensive accounts of this having been given by Shorten (1954) and Barnett (1958 and 1963). A consequence of neophobia is the delay experienced between laying a poison bait and the onset of feeding. This feature of behavior is the principal reason for the failure of acute rodenticides when pre-baiting is omitted; the use of anticoagulants eliminated the need for pre-baiting and improved the economics of effective rodent control.

The return to the use of acute poisons following the increasing incidence of warfarin resistance has prompted an investigation into the influence of odor in inducing rodents to feed at baits. This is a field be-devilled with old wife's tales and every rodent operator has his own (subjective) views on what constitutes an attractive bait. Unfortunately the factor of "attraction" by odor is nearly always confused by palatability, a point not made clear in the claims "an attractive bait," or "contains a special attractant."

The present studies were designed to investigate the effects of odor alone in attracting rats to feed at a given location; the effect of certain repellents was also investigated. Because under field conditions, odor gradients are highly variable and at the mercy of local weather conditions the studies were carried out in a colony of wild rats under more controlled conditions.

METHODS

A disused generating house was modified to provide a stable environment with controlled lighting and temperature. The experimental room was 18 ft. square and connected by 4 diameter drain pipe to a small concrete bunker housing a colony of 18 wild R. norvegicus. Twenty stainless steel feeding hoppers were fixed just above ground level at approximately equal intervals around the perimeter of the test room.

The gravity-feed hoppers were designed to allow only one rat to feed at a time but occasionally two small rats were observed jostling for position. The hoppers were pivotted so that the centre of gravity did not alter as they were emptied of food. The backs of the hoppers rested against micro-switches mounted on the wall and each was connected to a digital counter in an adjacent room. A counter was triggered by a rat placing its weight on the platform leading into the hopper trough. Time-lapse cinematography was used to photograph the counters at 15 minute intervals.

To avoid confusing palatability with odor attraction, the same food was placed in each hopper; chick pellets were used at first but when rats were observed to carry considerable numbers away, a chick crumb diet was substituted. It was planned to observe the rats under reversed lighting conditions but they failed to become completely acclimatised, possibly because of the existence of other cues of normal daily activity. Instead, the lights were set for a 12 hour day/12 hour night regime with four 60 watt red lights alight continuously to allow observations to be made at night.

Prior to the assay of potential attractant compounds, rat activity was recorded and the hoppers ranked in order of preference. Experimental compounds were then applied to the inner panel of the entrances to a number of the least preferred hoppers; special care was taken to ensure that the food did become contaminated by the compound. Repellent materials were applied in a similar way but only to those hoppers for which rats showed greatest preference. After each test, the room was scrubbed out and the experimental hoppers replaced with clean ones.

TESTS ON "ATTRACTANT" COMPOUNDS

Assays were made on the following natural and proprietary compounds, each of which has been attributed with "attractive" properties. Raw fish and beef; dried dog food; coconut oil; fresh blood and dried blood; chicken offal; cinnamal dehyde; raspberry powder flavour, Saroline FD 1909; Saroline FD 2664; Bush Boake Allen EC 6248; oil of aniseed; a commercial game "lure"; Brumoline, an anticoagulant rodenticide with sex attractant.

Pre-treatment counts for three days showed that most rat activity was confined to hoppers 2-10 and 20 but considerable daily fluctuations occurred at individual hoppers (Table 1). The addition of raw fish to hoppers 14-19 failed to influence rat activity to any appreciable extent over the next two days, but there was a slight tendency for the total activity to increase.

Table I: Rat activity before and after the labelling of non-preferred hoppers with fish.

Hopper Number	Pre-treatment Counts (3 days)			Fish Added	Test Counts (2 days)	
1	7	32	6		6	2
2	86	405	464		528	212
3	221	2129	669		1542	1620
4	15	25	289		164	194
5	975	200	3		238	361
6	1183	82	21		310	454
7	243	509	407		357	514
8	583	589	922		801	660
9	17	152	407		676	560
10	299	601	11		246	385
11	1	7	14		42	185
12	7	93	425		296	298
13	5	1	235		76	115
14	4	0	58	F	83	73
15	0	1	10	F	19	16
16	0	2	2	F	1	10
17	17	17	14	F	11	65
18	0	0	0	F	0	0
19	0	0	0	F	0	0
20	336	354	487		107	62
Total Counts	3999	5199	4744		5503	5786

The preference ranking of the hoppers was different for each test, probably resulting from the scrubbing out of the attractant area. In a test where three compounds were assayed consecutively, only the hoppers being changed, the hopper preferences were remarkably consistent, even though different groups of non-preferred hoppers were used to assay the three compounds (Table II). The feeding pattern changed slowly over the eleven day observation period; rats gradually stopped feeding at hoppers 6, 16 and 20 and concentrated their activity at hoppers 8, 9, 12 and 13.

Table II: Rat activity in response to three potential attractants.

Hopper Number	Pre-Treatment 1	2	Rasberry Powder Flavour Added	Days 3	4	5	Saroline F.D.1909 Added	Days 6	7	8	Cinnam-aldehyde Added	Days 9	10	11	Hopper Number
1	121	39		30	42	0		8	9	0	C	4	0	4	1
2	2	0		0	2	0		1	0	1	C	1	1	0	2
3	2	21		1	4	0		0	0	2	C	5	2	0	3
4	28	0	R	6	10	0		0	0	2	C	4	3	1	4
5	39	5		16	21	2		3	2	2		1	1	0	5
6	146	92		142	249	113		43	59	9		3	3	1	6
7	0	1		0	4	25		3	0	1		2	1	0	7
8	67	319		214	619	320		298	315	239		249	271	517	8
9	977	405		464	1156	746		700	639	673		504	459	358	9
10	673	184		132	285	177		221	238	180		28	79	66	10
11	1	0	R	0	4	1		0	0	0		1	1	0	11
12	480	27		279	475	213		200	261	313		288	473	274	12
13	496	183		100	189	136		185	132	246		459	275	186	13
14	10	2	R	0	3	0	S.1	1	0	0		2	0	0	14
15	3	6	R	4	7	0	S.1	0	2	0		2	1	1	15
16	90	215		104	189	80		7	8	16		59	58	98	16
17	0	1	R	0	4	0	S.1	0	0	0	C	3	0	0	17
18	0	0	R	0	3	0	S.1	2	0	0	C	0	0	0	18
19	0	0	R	1	3	0	S.1	0	0	0	C	0	1	0	19
20	402	225		422	643	35		161	162	92		3	2	0	20
Total Counts	3537	1725		1915	3912	1848		1833	1827	1776		1618	1595	1506	Total Counts

This suggested that hoppers might be 'labelled' with the odor of visiting rats and that this odor might lead to reinforcement of daily feeding.

In a further test, hoppers from points of greatest activity were exchanged with those from least preferred positions, (Table III), but the rats continued to feed at their accustomed locations.

None of the other compounds tested increased the activity of rats at the selected hoppers.

TESTS ON RAT ODOURS

Female rats in oestrous are highly attractive to males. Two female albino rats were caged for three days with a male to induce oestrous. The females were then caged for six

Table III: Rat activity before and after the exchange of hoppers from preferred to non-preferred positions.

Hopper Number	BEFORE EXCHANGE Fri.	Sat.	Mon. (2 day count)	Hopper Exchange	AFTER EXCHANGE Tues.	Wed.	Thur.
1	0	0	1		56	62	30
2	0	1	0		5	6	7
3	0	1	0		2	4	5
4	0	14	1		0	0	2
5	0	0	4		6	2	21
6	0	1	0		0	1	0
7	0	5	2		0	0	0
8	-	-	-		-	-	-
9	3	1	1		0	0	4
10	215	168	484		63	40	39
11	215	320	932		231	44	67
12	241	246	723		287	329	565
13	0	0	2		4	3	1
14	512	317	184		120	144	176
15	272	263	553		39	114	81
16	150	125	146		3	5	4
17	0	0	0		6	5	11
18	4	4	2		98	7	5
19	41	100	105		1160	511	41
20	-	-	-		-	-	-
Total Counts	1663	1566	3138		2090	1237	1069

hours daily on seven successive days in a small sealed chamber through which a very slow current of air was passed. The whole body odor of the females was collected by passing the expired air through a cold trap at 60°C. The condensates were tested daily in the attraction facility, but no significant increase in activity was elicited from the rat population. Similar tests on condensates obtained from male albino and wild rats also failed to induce changes in rat activity.

TESTS ON REPELLENTS

A number of materials are reported to be effective in preventing attack by rodents when incorporated in packing or other materials. The repellent effect is produced when animals come into oral contact, but some unpublished field reports suggested that odor may also be an important factor. Odor repellency could be useful in protecting properties from reinfestation. The following three compounds were tested.

(1) Unimerck Rodentifuge
(2) Latakia tobacco
(3) Phillips Petroleum Rotran 55

At the maximum recommended concentration of 1 part in 5000, the Unimerck rodentifuge showed no odour repellent properties.

Undiluted extracts of latakia tobacco (2g. leaf in 80 ml. isobutyl alcohol) were highly repellent and rat activity ceased at labelled hoppers. When these extracts were diluted 1:10 and 1:20 with water, the repellency was not so marked and labelled hoppers recorded appreciable rat activity. Further experiments in which hoppers were labelled only with the solvent isobutyl alcohol, resulted in complete cessation of rat activity for three days and very little recovery during the next three. In addition, latakia extracted in isopropanol failed to produce a consistent reduction of rat activity at labelled hoppers. The repellent activity must therefore be attributed to the solvent and not to the latakia tobacco.

In successive experiments, Rotran 55 was applied at 1%, 2.5% and 5% as an emulsion to hoppers. The 1% formulation gave slight but inconsistent repellency: the 2.5% and 5% formulations markedly reduced rat activity at the labelled hoppers but only for 3-4 days. When however the compound was mixed with food in the hoppers, strong repellency was observed and the effect continued for the 10 day recording sequence. This clearly demonstrated the need for oral contact if this repellent was to be effective for Rattus norvegicus.

DISCUSSION

There is a mass of evidence to show that odour plays an important part in the life of rodents and other mammals: territorial marking, mating, recognition of young and members of a family group, trail recognition and food detection (Howard and Marsh 1970).

Deer mice (Peromyscus maniculatus) have a striking ability to detect buried conifer seeds by odour (Howard and Cole 1967), and are still able to find seeds in complete darkness (Howard et al. 1968). The addition of sunflower oil or lecithin-mineral oil improved detection and palatability of four types of grain not normally fed on by mice.

For Rattus norvegicus, earlier workers have suggested that odour plays a minor part in its feeding behavior and the location of food (Liggett 1928). Although normal rats were able to locate 1/4" cubes of cheese buried in sawdust and anosmic rats were less able to find the cheese, a period of training was required before the rats associated the smell of cheese with a buried object and to distinguish cheese from pieces of cork used as controls. Liggett concluded that white rats do not follow an odour trail in a maze and that rats are influenced more by visual and auditory stimuli than by olfaction.

More recently, other workers have queried the validity of comparing olfactory responses of albino and wild rats. Differences in olfactory sensitivity could not be demonstrated between pigmented and albino rats (Moulton 1960) even though the olfactory bulbs of wild Norway rats were shown to be heavier and larger than those of the albino, (Holt 1917). Moreover, the bulbs of wild rats contained more of the granular cells thought to act in the reinforcement of olfactory stimuli, (Smith 1928).

The variable exploratory movements of rats tend to put them regularly in every accessible spot in a substantial area around their nest. This enables them to learn to locate food and water and to find new sources of food (Barnett 1963).

Their movements are accompanied by the sampling of all materials encountered, the stimuli being both smell and taste. Barnett postulates that odour leads to the initial sampling of food and this view is shared by Howard and Marsh (1970). Odours are, however, thought to be subordinate to other sensory cues in determining direction of movement by rats (Eayrs and Moulton 1960).

This view was supported (Calhoun 1963), by placing a new source of food away from the normal trails established by a colony of wild rats. They at first tended to follow the gradient of odor to its origin but, when stopped by a barrier fence, the rats returned to a known point of orientation from which they could respond to the odor, and at the same time, keep to a conditioned route of travel.

The failure of the present work to demonstrate attraction of rats by odor suggests that the two factors of attraction and palatability cannot be considered as separate functions, and that an initial attraction by odour must be reinforced by taste. It could be argued that the absence of air movement in the experimental conditions did not allow the development of odour gradients of sufficient magnitude to allow rats to respond to them. Moreover, air movements caused by convection from the heating system, heat from rat bodies, and movement of the rats around the room could possibly cause random dispersion of an odour throughout the room. Even if this were the case, one would expect a highly attractive odour to initiate exploratory behavior in rats to determine the source, similar to that observed by Calhoun (1963) when rats responded to the odour of garbage.

Responses of this kind have been observed on many occasions, but it is possible that the odour may service to detect a foodstuff which can correct nutritional inadequacies. Previous feeding experience also has a profound effect on the response of rats (Barnett and Spencer 1953); animals took several days to change their preference from one food to another even though their preference did become clearly marked after 4-5 days. It is not known whether previous exposure to odours will influence the subsequent response to rats without the animals having tasted it; the rejection of un-poisoned wheat by rats following a poisoning treatment with zinc phosphide on wheat suggests that texture and shape may be more important than odour or tastes.

Odor plays a considerable part in sexual activity and sex lures have been used successfully in insect control. Proprietary rodent baits are available "with added sex attractant" but the sex for which the attractant is designed is not specified! The use of sex attractants has considerable appeal to the public but their use in rodent control has yet to be substantiated.

The short series of tests on the effects of odour from female rats in oestrous failed to increase activity at labelled hoppers. This confirms observations by many workers that male rats in cages do not respond actively to oestrous females in adjacent cages. Once the males are in the same cage as the females then the normal mating sequence is established, following the initial olfactory investigation of the female by the male. A point often overlooked by advocates of the use of sex attractants in baits is that it is the males who are most active in sexual response, whereas the reproductive capacity of a colony is closely related to the number of females. The importance of this was demonstrated by Kennelly et al. (1970) who examined the fecundity of a rat population with 85% of sterile males and found that the total population differed only slightly from the numbers of animals in a similar colony with fully fertile males.

In the present experiments the odour of repellent compounds had only a small effect compared with that produced when animals come into oral contact. Barnett and Spencer (1953b) also showed that the odour of mercaptan reduced but did not completely inhibit rats feeding in a box treated with n-butylmercaptan. An effective odorous repellent could be valuable outdoors for protecting premises difficult to proof, or those highly susceptible to invasion by marauding rodents, but the powerful and objectionable smell of some compounds would preclude their use indoors, particularly in food manufacturing areas.

CONCLUSIONS

The present work confirms the outstanding preference of Rattus norvegicus to feed at an accustomed place. Under the experimental conditions described, odour appears to play a relatively unimportant part in feeding behavior when the rats are unable to confirm or reinforce by taste. The work also confirms a long standing personal view of the author and others in the field of rodent control, that it is unwise to put faith in a 'magical' approach for effective rodent control. Knowledge of the pest, correct placement of baits in adequate numbers and amount, the use of tracking dusts, proofing and good housekeeping are likely to remain the fundamentals of good rodent control for many years to come. As new methods or materials become available, these must be integrated with the current methods but not expected or hailed as miracles.

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REFERENCES

BARNETT, S. A. 1958. Experiments with 'neophobia' in wild and laboratory rats. Brit. J. Psychol. 49:195-201.

____________, 1963. The rat, a study in behavior. Methuen pp 288.

____________ and SPENCER, M. M. 1953a. Experiments on the food preferences of wild rats (Rattus norvegicus, Berkenhout). Journal of Hygiene 51(1): 16-34.

____________ and SPENCER, M. M. 1953b. Responses of wild rats to offensive smells and tastes. Brit. J. Anim. Behavior 1:32-37.

BOYLE, C. M. 1960. A case of apparent resistance of Rattus norvegicus Berkenhout to anticoagulant poisons. Nature (Lond.) 168(4749):5-7.

CALHOUN, J. B. 1963. The ecology and sociology of the Norway rat. U.S. Public Health Service Publication 1008:288 pp.

EAYRS, J. T. and MOULTON, D. G. 1960. Studies in olfactory acuity. 1. Measurement of olfactory thresholds in the rat. Quart. J. Exp. Psychol. 12:90-98.

FISH, H. S. and RICHTER, C. P. 1946. Comparative numbers of fungiform and foliate papillae on tongues of domestic and wild Norway rats. Proc. Soc. Exp. Biol. and Med. 63(2):352-355.

HOLT, C. M. 1917. Studies on the olfactory bulb of the albino rat. 1. Experiments to detect the effect of a defective diet and exercise on the weight of the olfactory bulb. J. Comp. Neurol. 27:201-234.

HOWARD, W. E. and COLE, R. E. 1967. Olfaction in seed detection by deer mice. Journal of Mammalogy 48(1):147-150.

____________ and MARSH, R. E. 1970. Olfaction in rodent control. Proc. 4th Vertebrate Pest Conference, pp 64-70.

____________, MARSH, R. E. and COLE, R. E. 1968. Food detection by deer mice using olfactory rather than visual cues. Animal Behaviour 16:13-17.

KENNELLY, J. J., JOHNS, B. E. and GARRISON, M. V. 1970. Fecundity of a Norway rat colony with 85% sterile males. Abstr. 39. 3rd Ann. Meeting of Soc. for Study of Reproduction, p. 20.

LIGGETT, J. R. 1928. Olfactory sensitivity of white rat. Genetic Psych. Monographs 3 No. 2 64 pp.

MOULTON, D. G. 1960. Studies in olfactory acuity. 5. The comparative olfactory sensitivity of pigmented and albino rats. Animal Behavior 8(3-4):129-133.

SHORTEN, M. 1954. The reaction of the brown rat towards changes in its environment. In "Control of Rats and Mice." Vol. II ed. D. Chitty Clarendon Press Oxford, pp 307-334.

SMITH, L. A. 1928. A comparison of the number of nerve cells in the olfactory bulbs of domesticated albino and wild Norway rats. J. Comp. Neurol. 45:483-501.